Saeed, Umar; Hämäläinen, Jyri; Mutafungwa, Edward; Wichman, Risto; Gonzalez, G. David; García-Lozano, Mario

On the Use of Existing 4G Small Cell Deployments for 5G V2N Communication

Published: 01/01/2019

Document Version
Peer-reviewed accepted author manuscript, also known as Final accepted manuscript or Post-print

Please cite the original version:
Saeed, U., Hämäläinen, J., Mutafungwa, E., Wichman, R., Gonzalez, G. D., & García-Lozano, M. (2019). *On the Use of Existing 4G Small Cell Deployments for 5G V2N Communication*. Abstract from European Conference on Networks and Communications, Valencia, Spain.

On the Use of Existing 4G Small Cell Deployments for 5G V2N Communication

Umar Saeed[1], Jyri Hämäläinen[1], Edward Mutafungwa[1], Risto Wichman[2],
David González G.[3], Mario Garcia-Lozano[4]
[1]*Department of Communications and Networking, Aalto University, Finland*
[2]*Department of Signal Processing and Acoustics, Aalto University, Finland*
[3]*Wireless Signals Technologies Group, Corporate Systems and Technology, Continental AG, Germany*
[4]*Department of Signal Theory and Communications, Universitat Politècnica de Catalunya (UPC), Spain*
Corresponding author: umar.saeed@aalto.fi

***Abstract*—We study the feasibility of the dense 4G and 5G cellular networks at sub-6 GHz and millimeter wave carriers for vehicle-to-network applications. For this purpose, road-side network coverage, signal-to-interference-plus-noise (SINR) and handover rate are used as key performance indicators (KPIs). The KPIs are calculated over realistic vehicular user routes which are created by Google Maps APIs. The channel pathloss is simulated using a ray tracing software and it is shown that even for a dense 4G small cell deployment the coverage at 28 GHz carrier frequency is very fragmented and thus, service continuity depends on the availability of sub-mmWave carriers.**

***Index Terms*—5G mobile communication, cellular V2X, millimeter wave propagation, performance analysis**

I. Introduction

Cellular vehicle-to-network (C-V2N) communication is a special case of vehicle-to-everything (V2X) connectivity scenarios. The mobile network standards like 4G LTE and, more recently, the fifth generation (5G) bring many advantages such as large service areas, centralized control and coordination, better quality-of-service (QoS) and security [1].

While 5G progress is motivating some fundamental changes in the existing architecture of 4G cellular networks, at this early phase the complete revamp of the legacy 4G networks is not seen to be reasonable from both economical and technical standpoints [2]. To that end, the 5G Non Standalone (NSA) architecture enables operators to provide 5G services in shorter time-frame and with lower cost by anchoring 5G radio access to existing 4G radio access and core network [3].

Accordingly, in this paper we investigate the feasibility of 5G mobile communication in a small cell deployment that was originally planned for 3G/4G service provision on 2 GHz carrier frequency. The focus is on the urban street coverage that provides a valuable starting point to develop V2N services. We consider 2.6 GHz, 5 GHz and 28 GHz carrier frequencies, and the radio channel characteristics have been modelled by using the WinProp ray tracing software. The use of 28 GHz has been discussed before [4] but there are also concerns on the applicability of this high carrier frequency for outdoor deployments. Thus, our aim is to contribute to this discussion from V2N coverage perspective.

This work was supported by Academy of Finland (grants 311752 and 287249). Work by Mario Garcia-Lozano was funded by the Spanish ministry of science through the project RTI2018-099880-B-C32, with ERFD funds.

TABLE I. Assumed BS capabilities

Parameter	Value			
	Macro BS	Small BS		
TX power	46 dBm	30 dBm		
Operation band	2.6 GHz	2.6 GHz	5 GHz	28 GHz
Bandwidth	20 MHz	20 MHz	100 MHz	500 MHz
Antenna gain	18 dBi	5 dBi		
Antenna height	30 m	10 m		
SINR threshold	-7 dB	-7 dB		

Fig. 1: Assumed network deployment in Vienna city. Macro BSs are denoted by red and small BSs by yellow markers.

Since the focus is on the V2N connectivity at street-level, we have developed a new methodology where the simulation statistics are created from a large number of realistic routes. Specifically, we have built a simulation environment whereby vehicular routes are formed by using the Google Maps APIs. Unlike classic radio network planning based on coverage with raster format, a route-based evaluation allows to expand the vision with a more complete picture of the expected QoS.

II. Network deployment and BS parameters

The network of Fig. 1 is composed of 17 macro BSs and a dense layer of 221 pico BSs planned by authors of [5]. The deployment resembles a realistic “half square cell plan” where small BSs are not placed close to macro BSs. In macro cell edges small cells have been located on the strategic hotpots and street corners. The network area is around 2.5 km in length and 2.5 km in width. In the performance analysis, we assume the capabilities of Tab. I for the macro and small BSs.

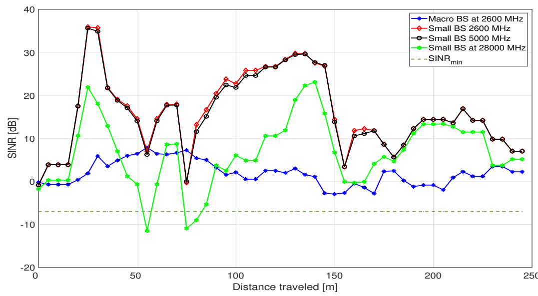

Fig. 2: The received SINR on the test route.

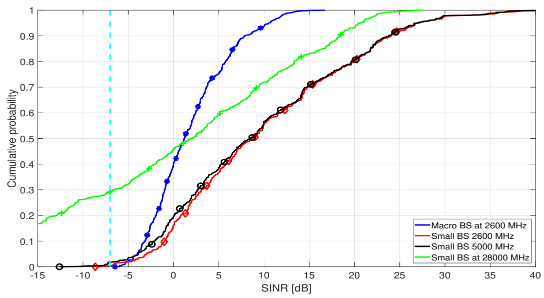

Fig. 3: The CDF of SINR over 100 randomly generated routes.

III. Performance Evaluation

A. Street coverage

In Fig. 2 we have the received SINR plotted on the first 250 m section of a test route. As expected, the SINR at 28 GHz carrier is in large part of the route low with sharp fluctuations dropping sometimes below the SINR threshold. However, the received SINR from small cells at 2.6 GHz and 5 GHz carriers is higher and overlapping almost all the time. The relative small difference between the SINRs received from these two carriers is due to the fact that the benefit from low propagation loss at 2.6 GHz is almost fully lost due to the higher co-channel interference. On the 28 GHz carrier co-channel interference does not play important role but coverage is degraded by the heavy propagation loss. Here, macro cells at 2.6 GHz act as a fallback option for the UE when there is no small cell coverage.

The CDFs of SINR for all carriers over 100 randomly generated routes are displayed in Fig. 3 and follow the same trend as at the test route. The dense deployment of small cells in street crossings has led to heavy interference at 2.6 GHz and 5 GHz carriers, thus, resulting in SINR distributions which are almost completely overlapping. At 28 GHz, carrier outage is about 30%. However, the small cells achieve almost full street coverage with 2.6 GHz and 5 GHz carriers. This essentially implies that the availability of 28 GHz carrier is not guaranteed for significant portions of the UE routes resulting in a very heterogeneous service quality due to the frequent switching to lower carriers.

B. Handovers between carriers

In order to understand the connection elasticity, we introduce Street Level Crossing Rate (SLCR) and Street Average Fade Duration (SAFD) as the performance indicators.

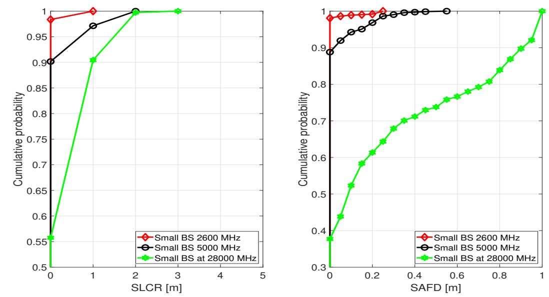

Fig. 4: The CDF of SCLR and SFAD calculated over 20 pixel segments of the 100 randomly generated routes.

The SLCR is closely related to the classical level crossing rate that is defined for fading channel power [6]. Here, we consider this measure for SINR and in spatial domain calculated over per 100 m segments of UE routes. That is, SLCR is used here to describe how fragmented is the connectivity on a certain carrier. Similarly, SAFD reflects the spatial duration of low SINR locations where connection might be lost.

The CDFs for SLCR and SAFD are shown in Fig. 4. It can be noticed from the SLCR curve for 28 GHz that about 55% of route segments have no level crossings at all. This, however, also includes segments which are either fully connected or not-connected at all. A more complete picture becomes clear when we look at the SAFD curve, which indicates that only about 38% of the route segments are fully connected. These fully connected segments lie either in the LOS of smalls BSs (around 22%) or in the nearby areas where shadow fading is not strong enough to fully block the coverage.

IV. Conclusions

This work focused on the feasibility study of 5G for V2N communication by leveraging the existing 4G small BS sites. A novel framework, integrating Google maps with radio environment, has enabled the QoS assessment for V2N communication using real world vehicular routes. It has been shown that for 4G network deployment where small cells are primarily meant to serve the macrocell edge users, coverage at sub-6 GHz carriers is good with less than 2% outage. However, coverage at 28 GHz is fragmented with about 30% outage. Therefore, it is concluded that even dense outdoor small cell deployments that are planned for sub-mmWave carriers needs to be densified if the 28 GHz carrier frequency is applied.

References

[1] 5GPPP, "White paper on automotive vertical sector, 5G Automotive vision," Tech. Rep., Oct. 2015.

[2] J. G. Andrews and et. al., "What will 5G be?" *IEEE JSAC*, vol. 32, no. 6, pp. 1065–1082, June 2014.

[3] GSMA, "Road to 5G: Introduction and migration," Tech. Rep., Apr. 2018.

[4] Z. Zhang, J. Ryu, S. Subramanian, and A. Sampath, "Coverage and channel characteristics of millimeter wave band using ray tracing," in *2015 IEEE ICC*, June 2015, pp. 1380–1385.

[5] H. Wang, M. Garcia-Lozano, E. Mutafungwa, X. Yin, and S. R. Boque, "Performance study of uplink and downlink splitting in ultradense highly loaded networks," *WCMC*, vol. 2018, no. xx, pp. 1–12, July 2018.

[6] G. L. Stüber, *Principles of Mobile Communication (2nd Ed.)*. Norwell, MA, USA: Kluwer Academic Publishers, 2001.